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Indian Standard

GUIDE FOR THERMAL ENDURANCE OF ENAMELLED AND VARNISH BONDED GLASS COVERED RECTANGULAR COPPER CONDUCTOR

UDC 621·315·337·4 : 620·199 (036)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 2

Winding Wires Sectional Committee, ETD 33

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Winding Wires Sectional Committee had been approved by the Electrotechnical Division Council.

The test method covered in this Standard is intended primarily for comparing the thermal endurance of enamelled and varnish bonded glass covered rectangular copper conductors in air at atmospheric pressure.

Similar standard for varnish bonded glass fibre covered rectangular copper conductors (IS 9778 : 1981) and for enamelled wires (IS 5825 : 1970) are also available.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GUIDE FOR THERMAL ENDURANCE OF ENAMELLED AND VARNISH BONDED GLASS COVERED RECTANGULAR COPPER CONDUCTOR

1 SCOPE

1.1 This guide lays down a test procedure for evaluating the useful life of enamelled and varnish bonded glass fibre lapped or braided rectangular copper conductors generally covered in IS 10114 : 1982. The grade of insulation shall be according to IS 10114 : 1982.

1.2 This standard does not apply to unenamelled glass fibre covered rectangular copper conductors.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
5825 : 1970	Guide for evaluation of thermal endurance of enamelled wires
9778 : 1981	Guide for evaluation of thermal endurance of varnish bonded glass fibre covered rectangular copper conductors
10114 : 1982	Enamelled and varnish bonded glass covered rectangular copper wires

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Wire

The insulated material as received.

3.2 Conductor

The bare metal after removal of both enamel and glass covering.

3.3 Increase in Dimensions Due to the Covering

The difference between the measurement of the thickness/total covering of the insulated conductor on the minor axis.

4 TEST SPECIMENS

4.1 Preparation of Test Specimens

Samples above 350 mm long of the enamelled and varnish bonded glass fibre covered conductor shall be bent flatwise through 180° around a mandrel having a diameter 10 times the bare thickness of the conductor. About 10 mm of the insulation is removed from one end of the specimen to facilitate electrical connection.

4.2 Number of Test Specimens

The number of test specimens required is 21 for each exposure temperature.

5 TEMPERATURE EXPOSURE

5.1 In Table 1 the suggested temperature and time of exposure in each cycle are given. A test cycle consists of exposure to high temperature, cooling to the room temperature and proof voltage testing. Unless otherwise specified, the test shall be carried out at a temperature of 15 to 35°C and a relative humidity in the range of 45 to 75 percent. Before the tests are made, the specimens shall be preconditioned under these atmospheric conditions for a time sufficient to allow the specimens to reach stability.

Thermal life values obtained from test specimens subjected to an average of less than 8 or more than 20 cycles at the exposure temperature may not be reliable and should not be used to predict the temperature rating of the insulated conductor. A shorter or longer cycle time than those given in Table 1 may, therefore, be chosen for certain exposure temperature to ensure that the average number of cycles to failure falls within this range.

5.2 It is essential that specimens be aged in an oven that will maintain the average temperature of the specimens within ± 2°C (temperature lower than or equal to 180°C) or ± 2°C (temperatures more than 180°C) of the desired value. At no time shall the temperature deviate by more than ± 2°C from the average regardless of the number of specimens in the oven. It is also preferable that the change of fresh air in the oven be controlled since there is reason to expect that the thermal degradation may be influenced by the fresh air change. There shall be approximately one complete change of fresh air per hour for each square metre of specimen surface.

Table 1 Suggested Temperatures and Exposure Times in Days per Cycle
(*Clause* 5.1)

Exposure Temperature Deg C	Estimated Range of Temperature Index of Insulated Conductors							
	120 129 Deg C	130 139 Deg C	140 149 Deg C	150 159 Deg C	160 169 Deg C	170 179 Deg C	180 189 Deg C	190 199 Deg C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
140	28	—	—	—	—	—	—	—
150	14	28	—	—	—	—	—	—
160	7	14	28	—	—	—	—	—
170	4	7	14	28	—	—	—	—
180	2	4	7	14	28	—	—	—
190	1	2	4	7	14	28	—	—
200	—	1	2	4	7	14	28	—
210	—	—	1	2	4	7	14	28
220	—	—	—	1	2	4	7	14
230	—	—	—	—	1	2	4	7
240	—	—	—	—	—	1	2	4
250	—	—	—	—	—	—	1	2
260	—	—	—	—	—	—	—	1

6 PROOF VOLTAGE TEST

6.1 The test specimens are removed from the oven and cooled to room temperature. To check the condition of the test specimens and to determine the end point of their useful life, each specimen is subjected to a proof voltage test at a frequency of 50 Hz according to the average thickness of the insulation in accordance with Table 2.

Table 2 Proof Voltage

Type of Insulation (as per IS 10114)	50 Hz Proof Voltage (Duration 1-minute) Volts
(1)	(2)
	volts
E1G1	330
E1G2	375
E1G3	435
E1G4	480
E2G1	630
E2G2	675
E2G3	735
E2G4	780

7 APPLICATION OF THE VOLTAGE

7.1 Each U-shaped specimen shall be placed inside a metal container which shall be filled as shown in Fig. 1 with nickel shots, nickel plated shots or stainless steel ball bearings not more than 2·0 mm in diameter, and maintained in a clean condition by washing it, for example, in tri-chloroethylene.

7.2 To detect failure, the over-current device shall operate when a current of 5 mA or more flows through the test voltage circuit. The test voltage source shall have a capacity to supply a current of 5 mA with a maximum voltage drop of 2 percent.

7.3 The proof voltage shall be applied between the bare conductor and the metal shots (which are earthed), for a period of 1 minute as shown in Fig. 1.

7.4 Care shall be taken in all cases to avoid mechanical damage of the test specimens. The specimens that fail to withstand the test voltage are discarded and the remaining ones are returned to the oven for the next cycle of temperature exposure.

8 CALCULATION

8.1 The cycles of temperature exposure, cooling and application of test voltage are continued until 11 specimens have failed at each exposure temperature.

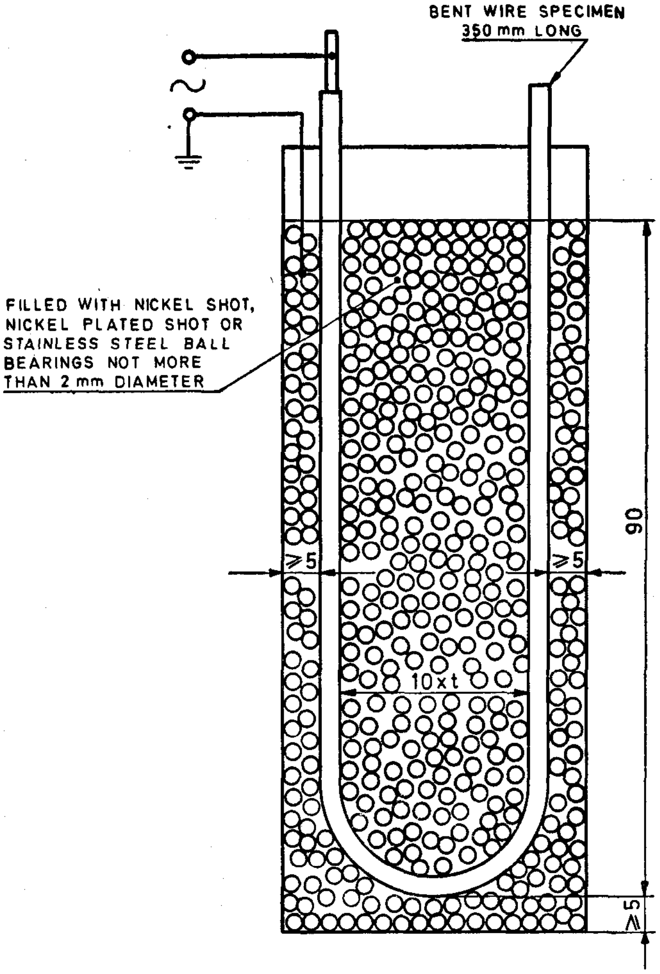
8.2 The median life of specimens at each ageing temperature is calculated by taking the failure time of the eleventh specimens, that is, the exposure time in hours taken to cause 11 specimens, to fail minus half the duration of cycle in hours.

8.3 The same is repeated at other exposure temperatures. The test specimens are subjected to 4 exposure temperatures out of which lower 3 temperatures should 20°C apart and the last two highest temperatures shall be at 10°C apart. It is recommended that the lowest ageing temperature should be 20°C above the anticipated temperature index for the enamelled and varnish bonded glass fibre lapped or braided rectangular copper conductors.

In the median life procedure, if median life of less than 100 hours is obtained at the highest exposure temperature, it should be disregarded.

The life temperature characteristic is plotted on a graph paper; the failure times are plotted with a logarithmic scale on the ordinate and the reciprocal of the absolute temperature as the abscissa and extrapolated to 20 000 hours.

The data so obtained may not permit accurate extrapolation in which case a statistical analysis of the thermal endurance test results, as given in Annex A, shall be carried out.


BENT WIRE SPECIMEN
350 mm LONG
~
FILLED WITH NICKEL SHOT, NICKEL PLATED SHOT OR STAINLESS STEEL BALL BEARINGS NOT MORE THAN 2 mm DIAMETER
⩾5
⩾5
10xt
90
⩾5

t = Nominal thickness of tape wrapped copper conductor in mm.

All dimensions in millimetres.

FIG. 1 ARRANGEMENT FOR BREAKDOWN VOLTAGE TEST USING SHOT BATH

ANNEX A

(*Clause* 8.3)

STATISTICAL ANALYSIS OF THE THERMAL ENDURANCE TEST RESULTS

A-1 STATISTICAL ANALYSIS OF THE THERMAL ENDURANCE TEST RESULTS

A-1.1 Method of Calculating Line of Best Fit

As the graphical fitting of a straight line to the plotted points does not always permit accurate extrapolation, the method of least squares shall be used for obtaining the line of best fit, as follows.

A-1.1.1 It is assumed that the specimens deteriorate in a manner expressed by the following equation:

$$L = Aeb/T \quad \dots \quad \dots \quad (1)$$

where

L = life of specimens,

A, b = constants for the specimens,

e = base of natural logarithms, and

T = absolute temperature in K.

A-1.1.1.1 Equation (1) may be expressed as a linear function by taking logarithms:

$$\text{Log}_{10} L = \log_{10} A + \frac{b}{T} \log_{10} e \qquad \ldots (2)$$

If $\gamma = \log_{10} L$, $a = \log_{10} A$, $b' = b \log_{10} e$, and $X = 1/T$,

then $\gamma = a + b' X \qquad \ldots \qquad \ldots (3)$

Hence, if data obtained from testing at higher temperatures are plotted on graph paper and so constructed that equal increments on the axes of abscissae and of ordinates respectively represent equal increments of $1/T$ and $\log L$, they may be expected to fall on a straight line. Such a line could be used for extrapolation to lower temperatures.

A-1.1.2 It may be found in practice that the data, when so plotted falls only approximately on a straight line. In this case a line of 'best fit' may be determined by the 'least squares' method, that is, by determining the regression Y upon X. The values of the constants of equation (3) are calculated as follows:

$$b' = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)/n}{\Sigma X^2 - (\Sigma X)^2/n} \ldots (4)$$

$$a = (\Sigma Y - b' \Sigma X)/n \qquad \ldots (5)$$

where

ΣXY = sum of products of X and Y,

ΣX = sum of values of X,

ΣY = sum of values of Y,

n = number of values of X (or of Y), and

ΣX^2 = sum of values of X^2

$$\text{But } T = \frac{I}{X} = b' (\log_{10} L - a) \qquad \ldots (6)$$

Hence T may be found for any value of L.

A-1.1.3 To simplify the handling of the test data used in the equation, it is suggested that it should be tabulated as in Table 3 and the calculation be performed as in the model set out below:

a) In col 1 and 2, list the measured exposure temperatures in °C and K;

b) In col 3 and 4, list the reciprocals and the squares of reciprocals of the absolute temperatures ($X = 1/T$ and $X^2 = 1/T^2$);

c) In col 5, list the corresponding lives (L) in hours;

d) In col 6, list the logarithms of the values in col 5 ($Y = \log_{10} L$);

e) In col 7, list the products of Y (from col 6) and X (from col 3);

f) Sum col 3, 4, 6 and 7 and enter the respective sums at the bottom of each column;

g) Enter the number of exposure temperature, n;

h) Use these sums and this number to calculate b' from equation (4);

j) Calculate 'a' from equation (5);

k) Substituting these values for a and b and 20 000 h for L in equation (6), find the corresponding value of T and hence of temperature in °C;

m) Repeat step (k) for a smaller value of L, for example, 2 000 h;

n) Plot the 'lives' and temperatures from (k) and (m) on log L versus $1/T$ graph paper and join them; this gives the regression line; and

p) On the same graph, plot the points representing average or median lives and corresponding temperatures.

Table 3 Suggested Layout of Data and Sample Calculation

Temperature °C (1)	 K (2)	$X = \frac{I}{T}$ (3)	$X^2 = \frac{I}{T^2}$ (4)	L (5)	$Y = \log_{10} L$ (6)	$\frac{XY = \log L}{T}$ (7)
180	453	2·207 51 × 10^{-3}	4·873 10 × 10^{-6}	—	—	—
200	473	2·114 14 × 10^{-3}	4·469 67 × 10^{-6}	—	—	—
210	483	2·070 39 × 10^{-3}	4·286 51 × 10^{-6}	—	—	—
220	493	2·028 40 × 10^{-3}	4·114 41 × 10^{-6}	—	—	—
n=		ΣX=	ΣX^2=		ΣY=	ΣXY=

NOTES

1 The values to be entered in col 5, 6 and 7 will depend on the experimental data.

2 The values in col 1 and 2 are only for example; the values in col 3 and 4 depend on values in col 1. These values do not imply that the glass fibre covered strip is necessarily tested at these test temperatures.

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